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Ozone synthesis in atmospheric pressure needle-to-plane gas discharge

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The research of negative, positive coronas and also a nonstationary streamer discharge was carried out. The synthesis of O_3 and emission spectrum of NO and atomic oxygen O on wave length 777.1 nm was investigated experimentally. The concept of ozone synthesis in atmospheric pressure gas discharge was offered.

1. Introduction

Most industrial ozone generators are the classical DBD setups. However, recently, attention is also attracted to ozone generators on high-pressure needle-to-plane gas discharge.

As is well known the basic reaction of ozone synthesis is $O_2 + O + M \rightarrow O_3 + M$. The concentrations of O_2 and M set by feeding gas composition. The main task is increasing of O generation efficiency, i.e. increasing of O_2 dissociation rate.

Electron energy distribution defines the dominant dissociative processes. Thus, it is possible to attempt to adjust discharge parameters with the purpose of effective generation of atomic oxygen, and therefore synthesis of ozone, if the chain of O_2 dissociation processes is known.

Nonstationary streamer discharge (SD), positive (PC) and negative (NC) coronas in the needle-to-plane electrode geometry was experimentally investigated. The analyses of peculiarities and similarity of physical processes of these discharges will allow determining the mechanism of dissociation O_2.

2. Experiment

The needle-to-plane electrode system was located in the hermetically chamber with controlled air feeding. The air pressure was an atmospheric. There was a possibility to apply to needle-electrode both positive and negative DC voltages. There was a quartz window in the chamber for registration of a radiation spectrum of discharge. There was no possibility to control O concentration. Therefore we observed the discharge byproducts such as O_3 and NO, and also radiation of atomic oxygen O on wave length 777.1 nm.

3. Results

For all three types of discharges the voltage-current characteristics with simultaneous monitoring of O_3 concentration were measured. The obtained dependences for the positive potential on the needle are represented in fig. 1.

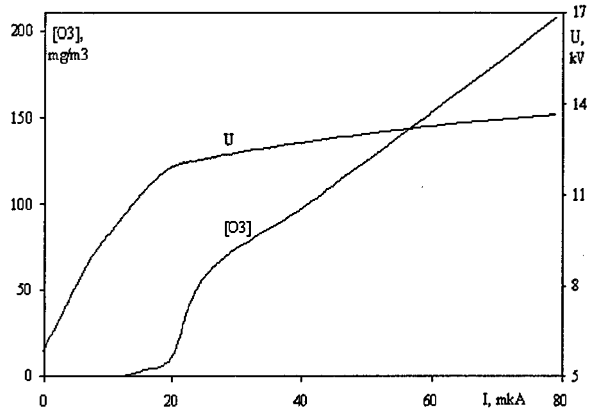

Fig. 1. V-I characteristic and O_3 concentration for the positive potential on the needle.

It is possible to observe the abrupt change on the current-voltage characteristic. This point separates the positive corona and nonstationary streamer discharge [1].

The radiation spectrums in a wave band 200÷300 nm were obtained with the purpose to register the γ-NO system (fig. 2) for all three types of discharges.

Some of the experimental and analytical results of physical processes of nonstationary streamer discharge, positive and negative coronas are presented in the table 1. Column 1 of this table is a power consumption w for ozone synthesis in SD, PC and NC normalized on power consumption of SD w_{sd}. Also, the ratios of γ-NO (0-1) intensity to intensity of $IV^+ N_2$ (0-1) ($I_{\gamma NO(0-1)}/I_{IV^+N_2(0-1)}$) and O-radiation (777.1 nm) intensity to $II^+ N_2$ (0-3) intensity $I_{O(777.1)}/I_{II^+N_2(0-3)}$ are presented in Columns 2 and 3 respectively. The Column 4 of the table explains the role of negative ions for SD, PC and NC [2].

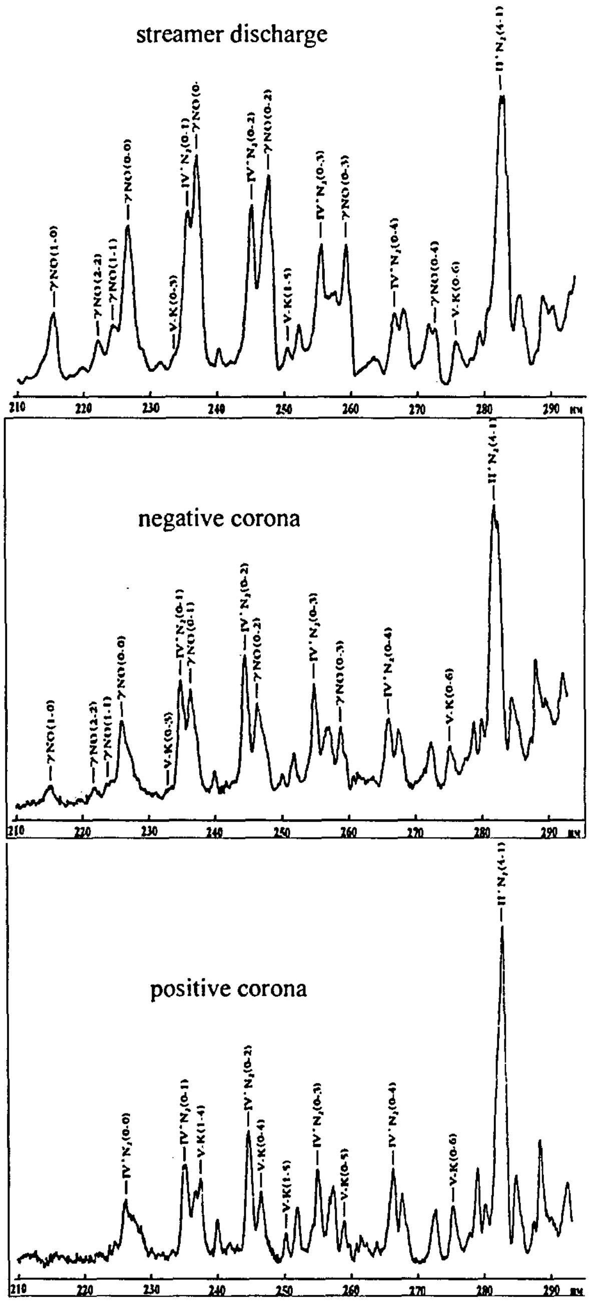

Fig. 2. Discharge radiation spectrum.

Table 1. Experimental results.

	1	2	3	4
	$\frac{W}{W_{sd}}$	$\frac{I_{\gamma NO(0-1)}}{I_{IV^{+}N_2(0-1)}}$	$\frac{I_{O(777.1)}}{I_{II^{+}N_2(0-3)}}$	Negative ions
SD	1	1.32	0.2	This mode is controlled by negative ions
NC	~2	0.91	0.1	Negative ions determine pulse regime
PC	>10	≈0	0.03	Negative ions practically are absent

4. Concept

Strong correlation between presence of negative ions in discharge, i.e. processes of attachment, and O_2 dissociation byproducts are observed (table 1). Thus, it is possible to conclude that the main channel of atomic oxygen generation is the process of dissociative attachment of electrons to O_2 molecules (table 2).

Table 2. The main dissociative processes.

№	Process	Threshold, eV	Ref.
1	$O_2 + e \rightarrow O^- + O$	4.2	[3]
2	$O_2 + e \rightarrow O + O + e$	5.58	[4]
3	$O_2 + e \rightarrow O + O(^1D) + e$	8.4	[5]

It is possible to draw a conclusion, that the processes of ionization and O_2 dissociation are separated in time and/or in space, and the atomic oxygen density can not be more then electron density in the current channel.

So, the effective dissociative processes must be realized in two stages. In the fist one the required level of ionization in the streamer channel can be reached by reduced electric field 1000 Td and more. In the second one the reduced electric field must quickly decrease to the value ~100 Td where processes from the table 2 effectively occur. The special shape of power pulse can optimize these conditions as against the DC power supply.

The present concept has allowed us to elaborate the ozone generator on nonstationary streamer discharge with following parameters: O_3 concentration - 2÷4 %, power consumption - 8÷13 Wh/gO_3, feeding gas – 20 % N_2 + 80 % O_2.

5. References

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